

Central Air Conditioner and Heat Pump Engineering Analysis: Comparison of the Reverse Engineering and Air Conditioning Industry Cost Estimates

U.S. Department of Energy

August, 1999

In addition to the manufacturing cost estimates provided by the Air-Conditioning and Refrigeration Institute (ARI) on behalf of air conditioner manufacturers, the Department conducted its own reverse engineering assessment (Rev-Eng) of the costs of producing air conditioning equipment under new standards. The Rev-Eng analysis had a threefold purpose: to independently validate the ARI results, to provide additional detail for use in the Engineering Analysis, and to develop the cost of current minimum efficiency equipment in absolute dollars.

ARI and Rev-Eng Methodologies

We and ARI agreed on a set of basic assumptions before ARI began collecting the relative cost data from their members. Then each ARI member who provided data estimated its own production costs for 1-1/2 ton, 3-ton, and 5-ton equipment under each new standard relative to its own current 10 SEER equipment. ARI then provided us with the mean, minimum, and maximum of these normalized responses for 3-ton equipment at each efficiency level (11 SEER through 15 SEER) in each product class.

The Rev-Eng analysis disassembled and inspected three 3-ton air conditioning units: a 10 SEER split air conditioner, a 10 SEER packaged heat pump, and a 12 SEER split heat pump. Information from these three “tear-downs” helped to construct a detailed production cost model that included the assembly and fabrication operations needed to produce equipment in each class. The Rev-Eng analysis also gathered from manufacturers and product literature key physical data on an additional 68 units and incorporated those data into the production models. Suppliers of parts, materials, and factory equipment provided additional cost information that allowed the Rev-Eng model to estimate the production cost of each of the 71 equipment models considered.

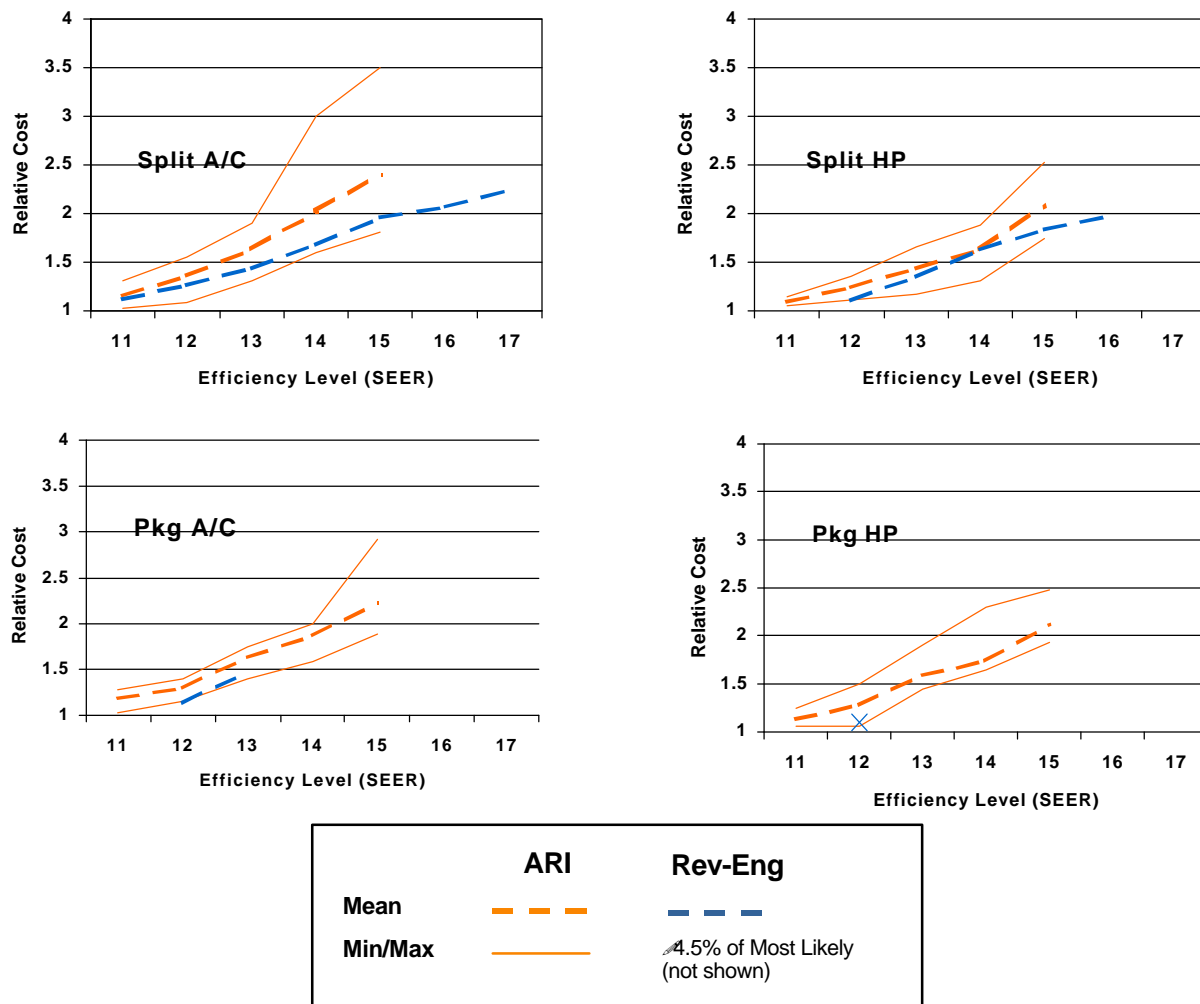
ARI and Rev-Eng Results

As Figures 1 illustrates, the ARI and Rev-Eng results overlap considerably, especially at the lower efficiency levels in the split air conditioning class and in the middle efficiency levels of the split heat pump class. This agreement is encouraging given the levels of uncertainty and variability involved in estimating representative production costs under a different efficiency baseline across a diverse industry. These area of convergence provide an excellent indication of the most likely costs of producing equipment utilizing today’s technology under new standard levels.

We and ARI continue to work to understand why the two sets of results disagree in some respects. In particular, we are concerned that the range between the Rev-Eng minimum and maximum relative costs at each efficiency level is much narrower than the range in ARI’s results. We assume that vigorous competition in the market for minimum-efficiency equipment will compel manufacturers to meet new standards for similar incremental costs, and that the market

cannot sustain as broad a range as ARI's results may imply. Also, the Rev-Eng production cost model is not able to reproduce ARI's maximum costs.

Figure 1: Comparison of ARI and Reverse Engineering Results



In addition to the differences in the ranges and maximum costs, the mean cost estimates do not agree perfectly. We and ARI have worked diligently to identify possible sources of those discrepancies. ARI has suggested we examine further such components as outdoor unit cabinet materials and labor, indoor coil materials, refrigerant, and packaging costs. We are also working with ARI to clarify the assumptions their members made in the following areas:

- *Essential features* “Essential” features are any product attributes that are required to meet minimum standards of operation, performance, and reliability at a given efficiency rating. We assume that baseline equipment sold under a higher efficiency standard will incorporate only those features that we consider essential.

- *Metal prices* We assumed flat 1998 sheet metal, copper, and aluminum prices in our cost assumption.
- *R-22 prices* We assumed flat 1998 R-22 prices.
- *Conversion costs* We assumed that a generic manufacturer builds a modern production facility dedicated to producing equipment at only one efficiency level. The plants display some differences in cost which we can consider conversion costs, but we have not explicitly accounted for converting production facilities to accommodate higher efficiency products.

The Rev-Eng results are given in *CAC Cost v2.4*. The spreadsheet provides detailed production cost estimates for representative equipment of each class at each efficiency level. *CAC Cost v2.4* also allows you to vary the cost elements to see the effect on the total cost of the system. The document that accompanies the spreadsheet provides further information.

The Department appreciates ARI's and its members' participation in the Engineering Analysis. Their relative cost results provide a solid foundation for further analysis, and their frequent review of and input to our validation effort is a valuable addition to our understanding of the production and design issues associated with meeting higher standards. We look forward to continuing the positive relationship as we seek to understand the remaining differences between our two sets of results.